

# INFLUENCE OF OPTICAL FIBER SENSOR PLACEMENT ON CFRP LAMINATES FOR PROCESS AND STRUCTURAL HEALTH MONITORING

H. Rocha<sup>1</sup>, M. Kumar<sup>1</sup>, J.P. Nunes<sup>1\*</sup>

<sup>1</sup> Institute for Polymers and Composites, University of Minho, Guimarães, Portugal

\* Corresponding author (jpn@dep.uminho.pt)

**Keywords:** *Structural Health Monitoring, Fibre Bragg grating sensor, Carbon Fibre Reinforced Polymer Composite, Process Monitoring, Barely Visible Impact Damage*

## Abstract

The use of fibre reinforced polymer (FRP) composites has been increasing in the last few decades in the aircraft and aerospace industries to replace metallic structures. The use of FRPs intends to increase the mechanical performance and decrease the weight ratios of structural parts, which allows to reduce fuel consumption, carbon dioxide emissions and, therefore costs [1].

Although composite materials hold promising achievements, their failure is still very difficult to predict, as it may result of a combination of defects, such as fibre breakage and/or misalignment, matrix macro or micro-cracking, material and stress discontinuities, fibre/matrix debonding, delaminations, etc [2]. Fatigue and aging might also lead FRP structures to failure, as they face repeated loading and harsh environmental conditions during their life-time [1], [3].

The eventuality of an unpredicted failure on a composite aircraft structure often requires an over-engineered design to comply with the rigorous and exigent safety rules of aerospace industry and, particularly, of civil aircraft, counteracting the initial purpose of using composites for weight reduction [4]. Aircraft and aerospace composites are prone to barely visible impact damage (BVID). It may occur during manufacturing or maintenance operations, with for example a drop of a hand tool, or in service due to heavy hail. These occurrences may lead to front face damage, and of more concern, transverse cracks, delaminations and/or fibres breakage, as they can go undetected by the human eye [5].

Not only civil and military aircraft structures, but also reusable launch vehicles (RLV) can benefit from structural health monitoring (SHM) systems [6]. The implementation of SHM systems is essential to ensure that such structures are intervened as needed upon damage, which might contribute to an extended lifetime in the harsh space environment they are exposed to [7]. Scheduled periodic inspections can be

avoided and, inspection and repair operations can be performed in a timely manner and focused on areas of need. SHM is a cost-effective approach that uses surface mounted or embedded sensors [1], and might be useful to develop new design principles, preventing over-designed structures [8].

Optical fibres (OF) with fibre Bragg grating (FBG) sensors is a matured technology regarding SHM [9]. FBG have proved to be able to monitor low impact damage, either under static or dynamic deformations [10]. FBG sensors have the advantage over other types of fibre optic sensors (FOS) of being intrinsic sensing elements, as the obtained signal is encoded directly in the wavelength form, easing wavelength division multiplexing [11].

This paper studies the influence of optical fibre location along the thickness of carbon fibre reinforced polymer (CFRP) laminates to detect BVID, particularly delaminations. Quasi-isotropic laminates made of epoxy reinforced with unidirectional carbon fibre fabric were produced by vacuum infusion. To minimize the impairment of OF embedment on the mechanical properties of the CFRP laminates, this work used OF with small-diameter, which were placed parallel to the direction of the adjacent reinforcing fibres. Specimens with OF at different locations along the thickness of the laminate were initially mechanically tested, through tensile and drop-weight impact testing, to evaluate the influence of the mechanical properties of the CFRP laminates. The embedment procedure of OF was assessed through X-ray computed tomography (XCT) analysis. Two OF locations were selected to be further evaluated. The samples were exposed to bending and impact testing and FBG signals were acquired from the sensors to evaluate whether defect detectability is dependent on OF location and distance to impact surface. Non-destructive analysis was used to evaluate the samples before (as is after production) and after mechanical testing and verify the suitability of the sensors to detect the induced damage.

Wavelength shift from FBG sensors was acquired from the beginning of the production process, allowing to monitor the curing stage. This procedure allowed to demould the laminates as soon as cure was finished.

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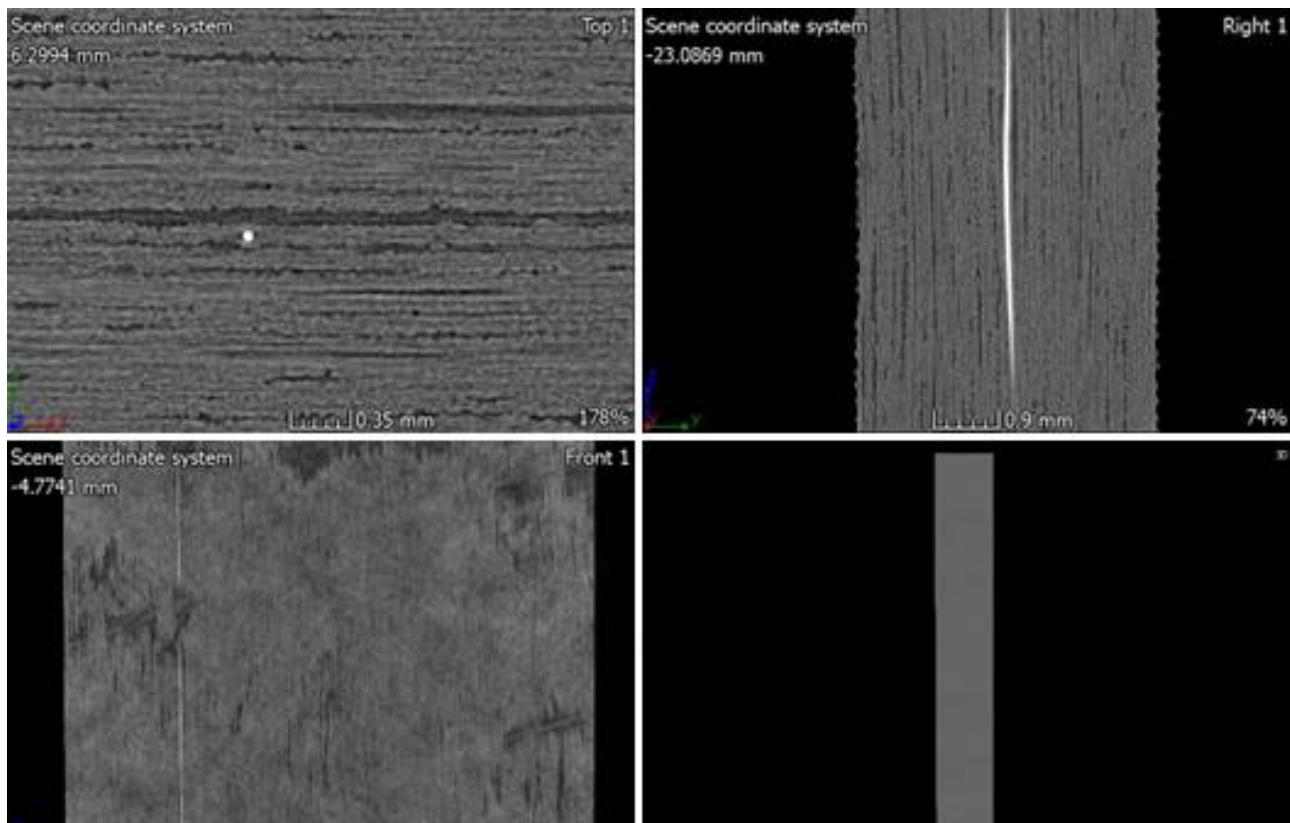


Fig. 1. Top, side and front XCT images of a tensile specimen of carbon fibre/epoxy composite with embedded optical fibre